US009462037B2

(12) **United States Patent**
Danziger et al.

(10) **Patent No.:** **US 9,462,037 B2**
(45) **Date of Patent:** **Oct. 4, 2016**

(54) **DYNAMICALLY SIZING CHUNKS IN A PARTIALLY LOADED SPREADSHEET MODEL**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Joshua Ari Danziger**, Metuchen, NJ (US); **Amod Karve**, Clifton, NJ (US); **Zachary Erik Lloyd**, Brooklyn, NY (US); **Yossi Kahlon**, Montclair, NJ (US); **Micah Lemonik**, Great Neck, NY (US)

(73) Assignee: **Google Inc.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 471 days.

(21) Appl. No.: **13/735,377**

(22) Filed: **Jan. 7, 2013**

(65) **Prior Publication Data**

US 2015/0195375 A1 Jul. 9, 2015

(51) **Int. Cl.**

G06F 15/16	(2006.01)
H04L 29/08	(2006.01)
G06F 17/22	(2006.01)
G06F 17/24	(2006.01)

(52) **U.S. Cl.**

CPC ***H04L 67/06*** (2013.01); ***G06F 17/2288*** (2013.01); ***G06F 17/246*** (2013.01); ***H04L 67/1002*** (2013.01)

(58) **Field of Classification Search**

CPC H04L 67/42; H04L 67/1002; H04L 65/1097; G06F 7/00; G06F 11/1448

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,528,743 A	6/1996	Tou et al.
5,758,358 A	5/1998	Ebbo
5,761,669 A	6/1998	Montague et al.
5,793,966 A	8/1998	Amstein et al.
5,895,476 A	4/1999	Orr et al.
5,930,813 A	7/1999	Padgett et al.
6,006,239 A	12/1999	Bhansali et al.
6,049,664 A	4/2000	Dale et al.
6,169,999 B1	1/2001	Kanno
6,243,706 B1	6/2001	Moreau et al.
6,327,584 B1	12/2001	Xian et al.
6,330,046 B1	12/2001	Ishitaka et al.
6,341,305 B2	1/2002	Wolfe
6,342,906 B1	1/2002	Kumar et al.
6,377,354 B1	4/2002	Nguyen et al.

(Continued)

OTHER PUBLICATIONS

Bibi et al., "A Platform for Delivering Multimedia Presentations on Cultural Heritage," 2010 14th Panhellenic Conference on Informatics, pp. 175-179.

(Continued)

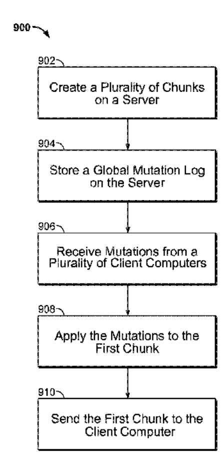
Primary Examiner — Yves Dalencourt

(74) *Attorney, Agent, or Firm* — Ropes & Gray LLP

(57) **ABSTRACT**

A method for managing a dynamically-sized chunked spreadsheet model on a server includes creating, on the server, a plurality of chunks representing a spreadsheet, where a first chunk in the plurality of chunks includes a first range of cells in the spreadsheet. The method further includes storing on the server a mutation log for the spreadsheet, and receiving a first plurality of mutations from a plurality of client computers, where the first plurality of mutations are stored in the mutation log. The method further includes applying the first plurality of mutations to the first chunk in response to a first client computer in the plurality of client computers requesting the first range of cells, and sending the first chunk to the first client computer.

22 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,418,441 B1 7/2002 Call
6,501,779 B1 12/2002 McLaughlin et al.
6,512,531 B1 1/2003 Gartland
6,662,210 B1 12/2003 Carleton et al.
6,705,584 B2 3/2004 Hiroshima et al.
6,717,593 B1 4/2004 Jennings
6,737,289 B2 5/2004 Woo et al.
6,879,997 B1 4/2005 Ketola et al.
6,967,704 B2 11/2005 Hoshino
6,972,748 B1 12/2005 Lang
6,983,416 B1 1/2006 Bae et al.
7,009,626 B2 3/2006 Anwar
7,026,100 B2 4/2006 Nakata et al.
7,031,954 B1 4/2006 Kirsch
7,035,910 B1 4/2006 Dutta et al.
7,039,643 B2 5/2006 Sena et al.
7,231,597 B1 6/2007 Braun et al.
7,233,951 B1 6/2007 Gainer et al.
7,287,094 B2 10/2007 Mogul
7,437,421 B2 10/2008 Bhogal et al.
7,478,330 B1 1/2009 Branson et al.
7,487,448 B2 2/2009 Emerson et al.
7,491,399 B2 2/2009 Vakharia
7,529,778 B1 5/2009 Dewey et al.
7,624,145 B2 11/2009 Junuzovic et al.
7,656,543 B2 2/2010 Atkins
7,680,932 B2 3/2010 Defaix et al.
7,698,379 B2 4/2010 Dutta et al.
7,712,016 B2 5/2010 Jones et al.
7,774,703 B2 8/2010 Junuzovic et al.
7,792,788 B2 9/2010 Melmon et al.
7,836,148 B2 11/2010 Popp et al.
7,890,928 B2 2/2011 Patrudu
7,920,240 B2 4/2011 Yonemura
7,953,696 B2 5/2011 Davis et al.
7,958,448 B2 6/2011 Fattic, II et al.
7,983,416 B2 7/2011 Takashima et al.
8,019,780 B1 9/2011 Pinkerton et al.
8,044,961 B2 10/2011 Opstad et al.
8,065,604 B2 11/2011 Blankinship
8,073,812 B2 12/2011 Curtis et al.
8,327,127 B2 12/2012 Suryanarayana et al.
8,327,812 B2 12/2012 Vuk
8,395,733 B2 3/2013 Ataka et al.
2001/0033917 A1 10/2001 Sogabe et al.
2002/0032701 A1 3/2002 Gao et al.
2002/0035580 A1 3/2002 Tanabe
2002/0091747 A1* 7/2002 Rehg et al. 709/107
2002/0095399 A1 7/2002 Devine et al.
2002/0133492 A1 9/2002 Goldstein et al.
2002/0174085 A1 11/2002 Nelson et al.
2003/0009603 A1 1/2003 Ruths et al.
2003/0014406 A1 1/2003 Faieta et al.
2003/0014513 A1 1/2003 Ruths et al.
2003/0018719 A1 1/2003 Ruths et al.
2003/0037076 A1 2/2003 Bravery et al.
2003/0037303 A1 2/2003 Bodlaender et al.
2003/0084078 A1 5/2003 Torii et al.
2003/0115268 A1 6/2003 Esposito
2003/0179230 A1 9/2003 Seidman
2004/0015781 A1 1/2004 Brown et al.
2004/0044965 A1 3/2004 Toyama et al.
2004/0085354 A1 5/2004 Massand
2004/0088374 A1 5/2004 Webb et al.
2004/0088653 A1 5/2004 Bell et al.
2004/0133444 A1 7/2004 Defaix et al.
2004/0215672 A1 10/2004 Pfitzner
2004/0215825 A1 10/2004 Pfitzner
2004/0215826 A1 10/2004 Pfitzner
2004/0216090 A1 10/2004 Kaler et al.
2005/0091291 A1 4/2005 Kaler et al.
2005/0125461 A1 6/2005 Filz
2005/0131887 A1 6/2005 Rohrabaugh et al.
2005/0185636 A1 8/2005 Bucher
2005/0200896 A1 9/2005 Narusawa et al.
2005/0234943 A1 10/2005 Clarke
2006/0031751 A1 2/2006 Ehud
2006/0075332 A1 4/2006 Fairweather et al.
2006/0101071 A1 5/2006 Henderson
2006/0200755 A1 9/2006 Melmon et al.
2006/0230344 A1 10/2006 Jennings et al.
2006/0248121 A1 11/2006 Cacenco et al.
2007/0033654 A1 2/2007 Wilson
2007/0061714 A1 3/2007 Stuple et al.
2007/0070066 A1 3/2007 Bakhash
2007/0073899 A1 3/2007 Judge et al.
2007/0094601 A1 4/2007 Greenberg et al.
2007/0186157 A1 8/2007 Walker et al.
2007/0208992 A1 9/2007 Koren
2007/0220068 A1 9/2007 Thompson et al.
2007/0233811 A1 10/2007 Rochelle et al.
2007/0239695 A1 10/2007 Chakra et al.
2007/0279572 A1 12/2007 Yonemura
2007/0288637 A1 12/2007 Layton et al.
2007/0299857 A1 12/2007 Gwozdz et al.
2008/0028302 A1 1/2008 Meschkat
2008/0040659 A1 2/2008 Doyle
2008/0059539 A1 3/2008 Chin et al.
2008/0082604 A1 4/2008 Mansour et al.
2008/0126943 A1 5/2008 Parasnis et al.
2009/0112990 A1 4/2009 Campbell et al.
2009/0192845 A1 7/2009 Gudipaty et al.
2009/0235181 A1 9/2009 Saliba et al.
2009/0276455 A1 11/2009 Yu et al.
2009/0328063 A1 12/2009 Corvera et al.
2010/0030578 A1 2/2010 Siddique et al.
2010/0083096 A1 4/2010 Dupuis-Latour et al.
2010/0107048 A1 4/2010 Takahara
2010/0153948 A1 6/2010 Schreiber et al.
2010/0218099 A1 8/2010 van Melle et al.
2010/0235763 A1 9/2010 Massand
2010/0241749 A1 9/2010 Rasmussen et al.
2010/0245256 A1 9/2010 Estrada et al.
2010/0251122 A1 9/2010 Lee et al.
2011/0055329 A1 3/2011 Abt, Jr. et al.
2011/0066957 A1 3/2011 Prats et al.
2011/0085211 A1 4/2011 King et al.
2011/0154185 A1 6/2011 Kern et al.
2011/0178981 A1 7/2011 Bowen et al.
2011/0252300 A1 10/2011 Lloyd et al.
2011/0252339 A1 10/2011 Lemonik et al.
2011/0302194 A1* 12/2011 Gonzalez et al. 707/769
2011/0302237 A1 12/2011 Knight et al.
2012/0072819 A1 3/2012 Lindner et al.
2012/0110445 A1 5/2012 Greenspan et al.
2012/0159298 A1 6/2012 Fisher et al.
2012/0331373 A1 12/2012 Lindner et al.
2013/0007183 A1* 1/2013 Sorenson et al. 709/213
2013/0159832 A1 6/2013 Ingargiola et al.
2013/0262974 A1* 10/2013 Anstis G06F 17/246
715/217

OTHER PUBLICATIONS

Ellis et al., "Concurrency Control in Groupware Systems," ACM 1989, pp. 399-407.

Huang et al., "A General Purpose Virtual Collaboration Room," Google 1999, pp. 1-9.

Pacull et al., "Duplex: A Distributed Collaborative Editing Environment in Large Scale," ACM 1994, pp. 165-173.

Cairns et al., "System and Method of Document Embedding in Collaborative Editors," unpublished U.S. Appl. No. 13/493,672, filed Jun. 11, 2012, 1-48.

Ellis et al., Groupware Some Issues and Experiences, Communications of the Association for Computing Machinery, ACM, 34:1, Jan. 1, 1991,38-58.

Cairns, "System and Method of Secure Communication Between Multiple Child Frames," unpublished U.S. Appl. No. 13/493,798, filed Jun. 11, 2012, 1-47.

Day-Richter et al., "System and Method for Managing Remote Procedure Calls Relating to a Third Party Software Application," unpublished U.S. Appl. No. 13/591,851, filed Aug. 22, 2012, pp. 1-98.

(56) **References Cited**

OTHER PUBLICATIONS

Day-Richter et al., "System and Method for Performing Data Management in a Collaborative Development Environment," unpublished U.S. Appl. No. 13/591,734, filed Aug. 22, 2012, pp. 1-101.

Grieve et al., "Systems and Methods for Collaborative Document Editing," unpublished U.S. Appl. No. 13/297,762, filed Nov. 16, 2011, pp. 1-49.

Kjaer, "Timing and Synchronization in JavaScript", Dev. Opera, Sections:"The Basics", "Event Queing", "Long Running Scripts" and "Advice on Timing", Feb. 27, 2007, downloaded from URL: http/dev.opera.com/articles/view/timing-and-synchronization-injavascript/, pp. 1-9.

Lemonik et al., "System and Method for Providing Data Management Services," unpublished U.S. Appl. No. 13/224,860, filed Sep. 2, 2011, pp. 1-88.

Lemonik et al., "System and Method for Using a Third-Party Add-On in a Collaborative Online Software Development Environment," unpublished U.S. Appl. No. 13/551,859, filed Jul. 18, 2012, 1-103.

Lemonik et al., "System and Method for Providing Access to a Document Associated with a Third Party Software Application Via Interframe Communication," unpublished U.S. Appl. No. 13/224,769, filed Sep. 2, 2011, pp. 1-90.

Lemonik et al., "System and Method for Providing Real-Time Collaborative Document Editing Services," unpublished U.S. Appl. No. 13/224,573, filed Sep. 2, 2011, pp. 1-90.

Lemonik et al., "System and Method for Updating an Object Instance Based on Instructions Received from Multiple Devices," unpublished U.S. Appl. No. 13/282,636, filed Oct. 17, 2011, pp. 1-91.

Lemonik et al., "System and Method for Updating an Object Instance Based on Instructions Received from Multiple Devices," unpublished U.S. Appl. No. 13/224,479, filed Sep. 2, 2011, pp. 1-91.

Lemonik et al., "System and Method for Using a Third-System and Method for Using a Third-Party Add-On to Manipulate a Document in a Collaborative Online Software Development Environment," unpublished U.S. Appl. No. 13/551,772, filed Jul. 18, 2012, 1-119.

Lemonik et al., "System and Method to Provide Collaborative Document Processing Services Via Interframe Communication," unpublished U.S. Appl. No. 13/224,663, filed Sep. 2, 2011, pp. 1-90.

Pereira et al., Merging Electronic Document Redraws, unpublished U.S. Appl. No. 13/282,753, filed Oct. 27, 2011, pp. 1-30.

Pereira et al., Merging Electronic Document Redraws, unpublished U.S. Appl. No. 13/006,259, filed Jan. 13, 2011, pp. 1-30.

Quinn, "Comparing Online vs. Traditional Office Software, Will desktop or online office software fit your non-profit needs best?" May 21, 2010, courtesy of Idealware, TechSoup.org [online]. Retrieved from the Internet L:http://www.techsoup.org/learning.center/software/page11852.cfm (4 pp.).

Sun et al., "Operational Transformation in Real-Time Group Editors: Issues, Algorithms, and Achievements," 1998, ACM Conference on Computer-Supported Cooperative Work, pp. 1-10.

Shen et al., "Flexible Merging for Asynchronouse Collaborative Systems," Griffith University, School of Computing an Information Technology, Brisbane, Australia 2002 (18 pages).

Tyson, Herb, "Microsoft Word 2007 Bible," 2007, pp. 112-115, p. 467, pp. 523-525, p. 798.

Wikipedia, the free encyclopedia, "Model-View-Controller," downloaded on Nov. 16, 2010 [online]. Retrieved from the Internet: URL:http://en.wikipedia.org/wiki/Modei%E2%80%93view%E2%80%93controller, pp. 1-10.

Citro, "Conflict Management for Real-Time Collaborative Editing in Mobile Replicated Architectures," 2007, Australian Computer Society, Inc., Thirteenth Austrailian Computer Science Conference (ACSC2007), pp. 115-124.

Conner, Zoho 4 Everyone, 2008, downloaded from the internet http://techbus.safaribooksonline.com/print?xmlid=9780768687835/ch01lev1 sec1, Aug. 21, 2012, p. 1-17.

DeJean, David, "Online office apps get real: Google Docs vs. ThinkFree vs. Zoho, Web-based suites have become real challengers to desktop applications," Jul. 16, 2008, Computerworld [online]. Retrieved from the Internet: <URL: http://www .computerworld . com/s/article/pri nt/91 08799/0n line_ office_ apps get_real_ Google D ocs vs ThinkFree vs. Zoho> (7 pp.).

Wikipedia, "Operational Transformation," http://en.wikipedia.org/wiki/Operation_transformation, Jun. 3, 2008. Retrieved from Internet: http://web.archive.org/web/20080603061805/http://en.wikipedia.org/wiki/Operational_transformation.

Unpublished U.S. Appl. No. 13/224,530, filed Sep. 2, 2011.

Unpublished U.S. Appl. No. 13/274,382, filed Oct. 17, 2011.

Unpublished U.S. Appl. No. 13/166,844, filed Jun. 23, 2011.

Wang et al. Google Wave Operational Transformation, Jul. 1, 2010, 1-6, retrieved from the Internet Feb. 14, 2012: http:/1 wave-protocol.googlecode.comfhg/Whitepapers/operational-transform/operational-transform.html.

Googlepedia: The Ultimate Google Resource, Third Edition, pp. 276-287 (2008).

Hodel et al., "Supporting Collaborative Layouting in Word Processing," University of Zurich, Department of lnforamtics; Zurich, Switzerland, 2004 (18 page).

Holzer, "Google Docs 4 Everyone" http://www.scribd.com/doc/14119795/Google-Docs-4-Everyone Published Feb. 2009.

Ignat et al., "Awareness of Concurrent Changes in Distributed Software Development," Nancy-Universite, France 2008 (9 pages).

Ignat et al., "CoDoc: Multi-mode Collaboration over Docuemtns," ETII Surich,Institute for Information Systems; Zurich, Switzerland, 2004 (15 pages).

Raman, "Cloud Computing and Equal Access for All," Google Inc. 2008 (4 pages).

Shen et al., "Integrating Advanced Collaborative Capabilitites into Web-Based Word Processors," Nauyang Technological University, School of Computer Engineering, Singapore 2007 (8 pages).

Using Adobe Buzzword, 2008, pp. 1-35.

Nasir et al., "Collaborative Report Creation System for Industrial Use," Yamagata University, Graduate School of Science and Engineering; Yamagata, Japan 2009 (6 pages).

Cayenne-McCall, "Synchronous 3D Document Collaboration," Pace University, Department of Computer Science; Nov. 2008. (42 Pages).

Abraham et al., "Mutation Operators for Spreadsheets," Software Engineering, IEEE Transactions on, vol. 35, No. 1, pp. 94,108, Jan.-Feb. 2009 doi: 10.1109/TSE.2008.73 URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4609389&isnumber=4771845.

* cited by examiner

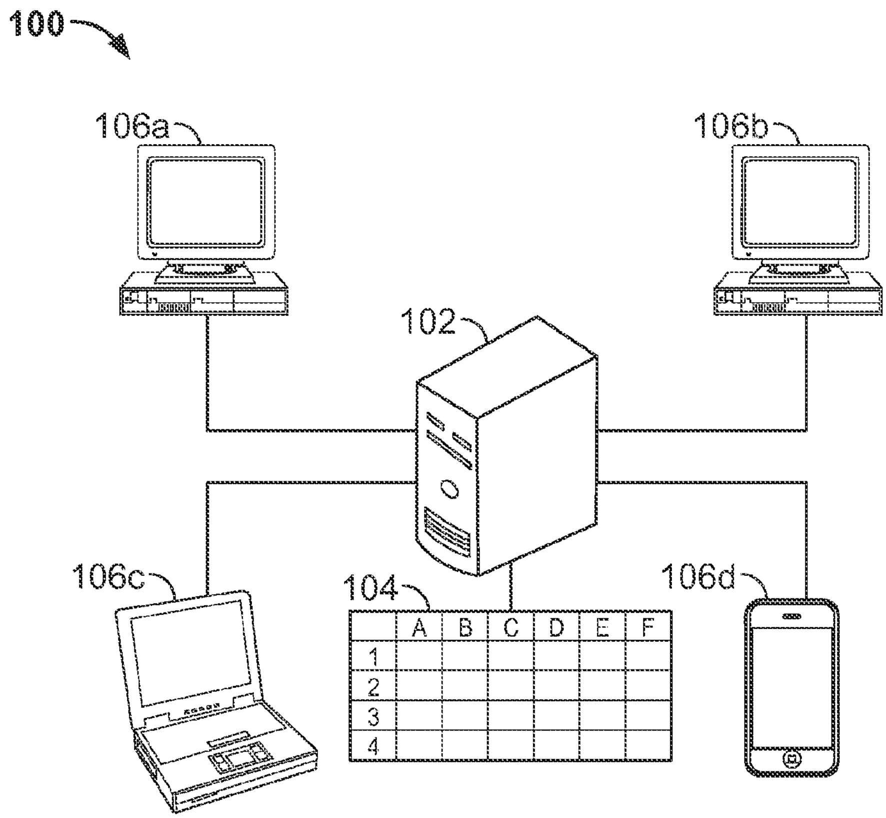

100
106a
106b
102
106c
104
106d
A
B
C
D
E
F
1
2
3
4

FIG. 1

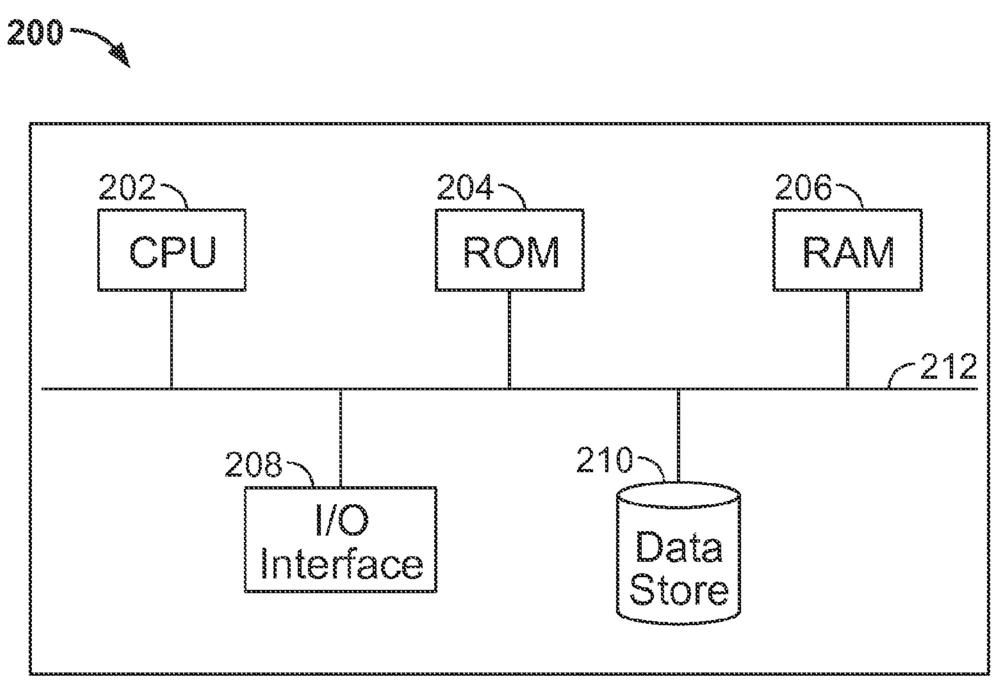

200
202
CPU
204
ROM
206
RAM
212
208
I/O Interface
210
Data Store

FIG. 2

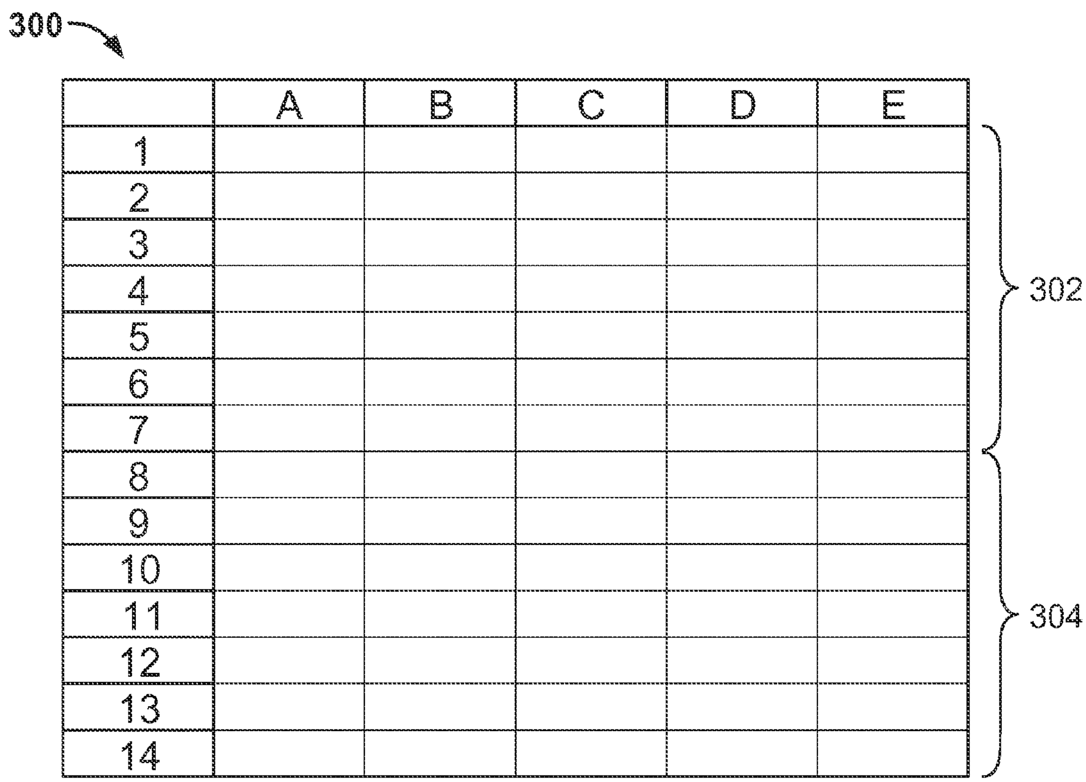


FIG. 3

400

A	Set A2 = 2	
B	Set A3 = 4	
C	Set B3 = A2+A3	
D	Set C10 = A2 x A3	
E	Set E9 = B3 + C10	Snapshot S1
F	Set D1 = 3	
G	Set D12 = 7	
H	Set A3 = 5	
I	Delete Row 6	
J	Add Row 11	Snapshot S2
K	Set E4 = 9	
L	Delete D12	

FIG. 4

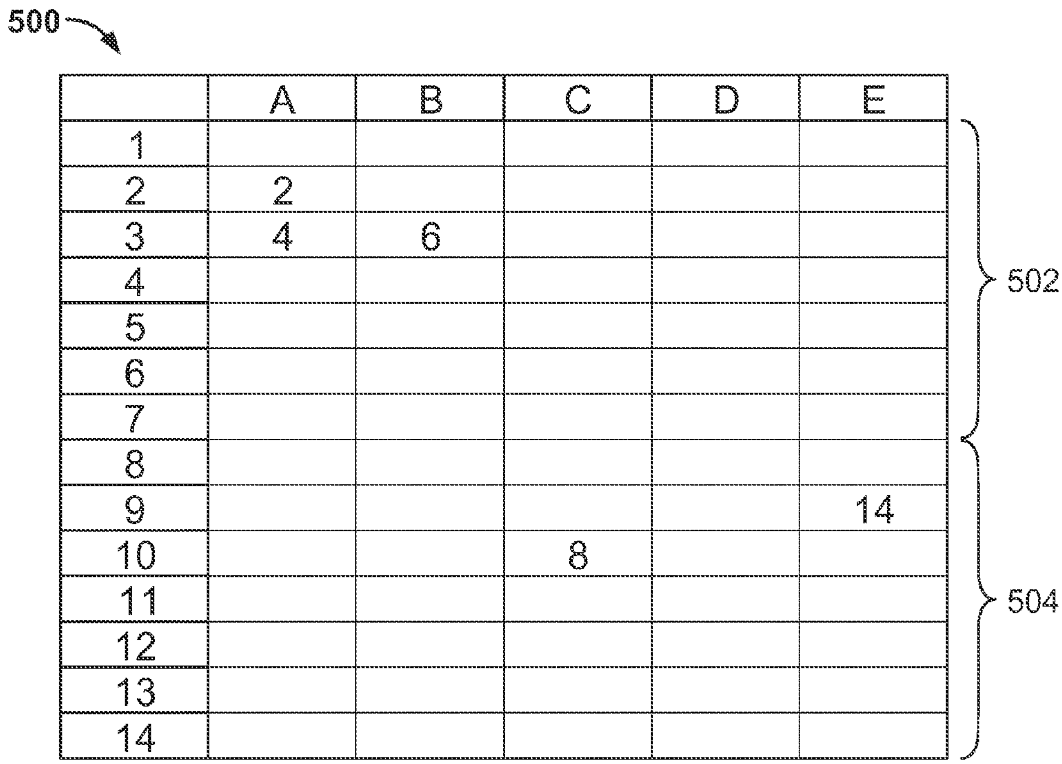

500
A
B
C
D
E
1
2
3
4
5
6
7
8
9
10
11
12
13
14
2
4
6
14
8
502
504

FIG. 5

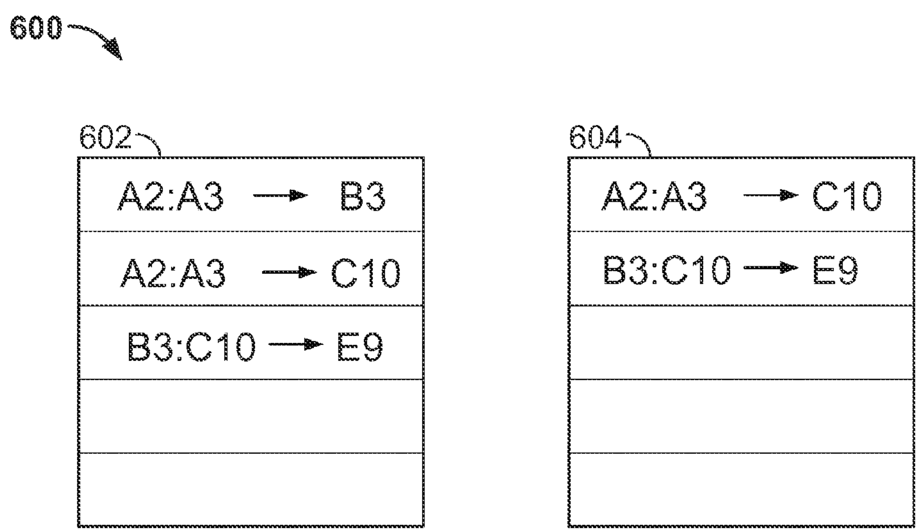

600
602
A2:A3 → B3
A2:A3 → C10
B3:C10 → E9
604
A2:A3 → C10
B3:C10 → E9

FIG. 6

700

	A	B	C	D	E
1				3	
2	2				
3	5	7			
4					
5					
6					
7					
8					17
9			10		
10					
11					
12				7	
13					
14					

702

704

FIG. 7

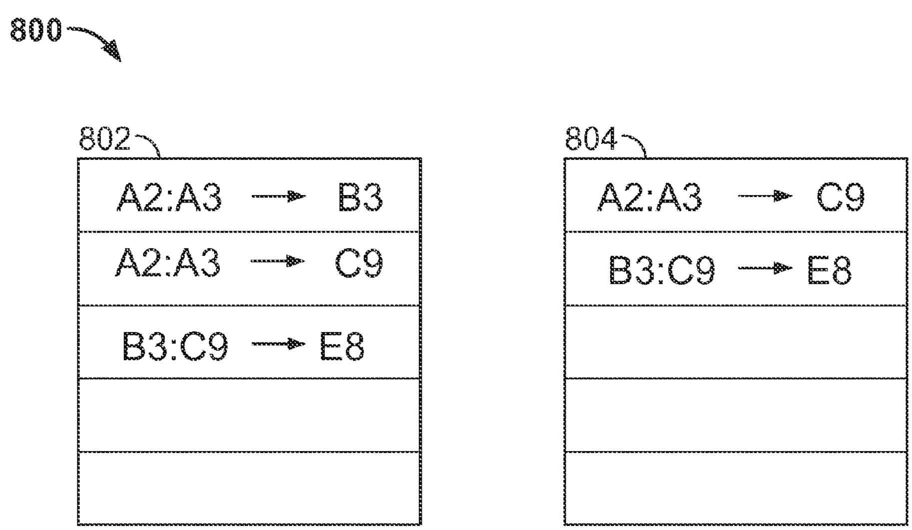


FIG. 8

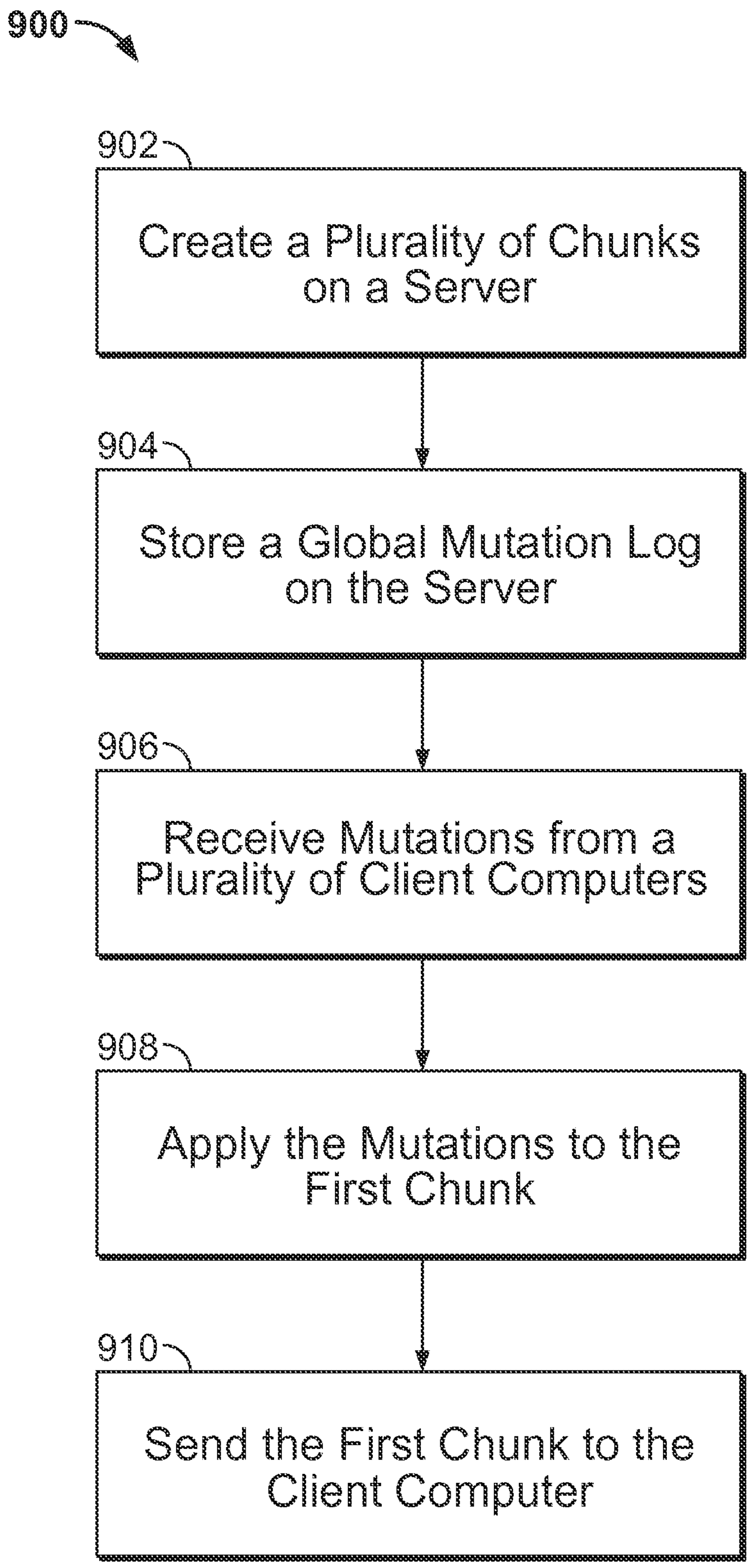

900
902
Create a Plurality of Chunks on a Server
904
Store a Global Mutation Log on the Server
906
Receive Mutations from a Plurality of Client Computers
908
Apply the Mutations to the First Chunk
910
Send the First Chunk to the Client Computer

FIG. 9

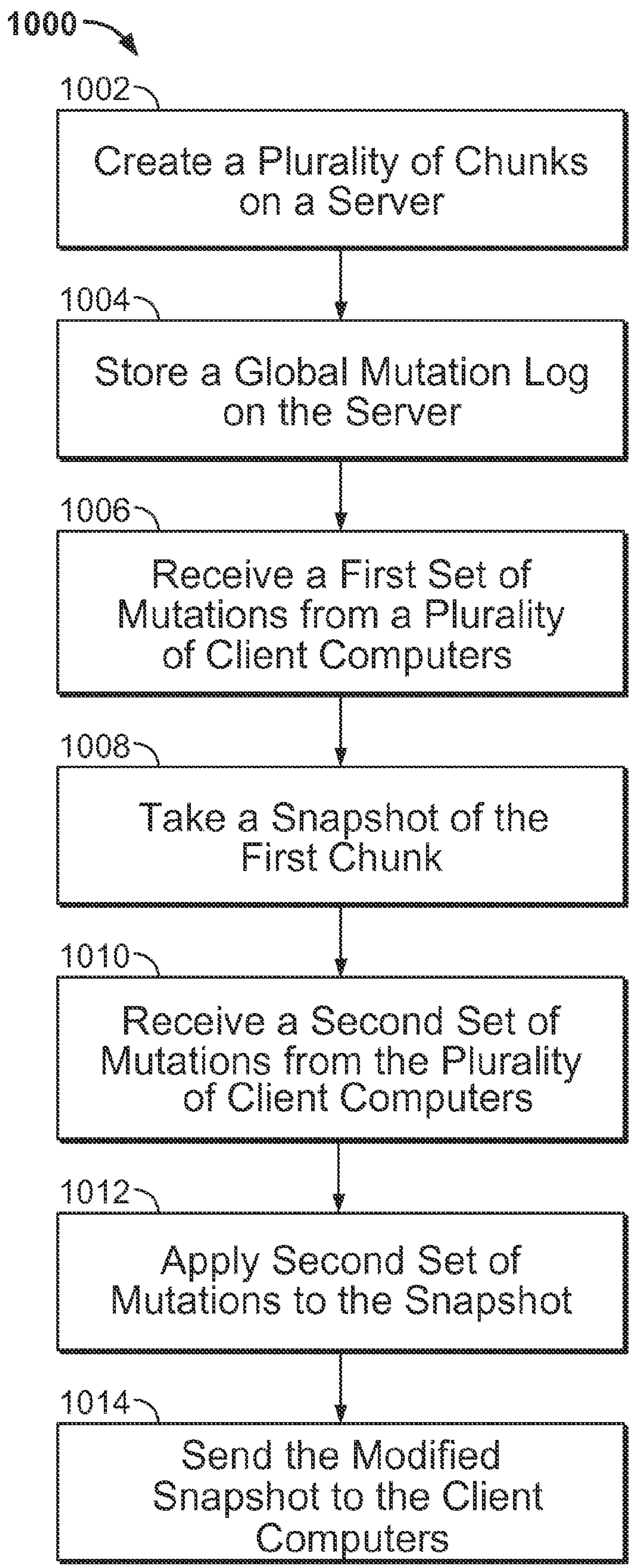

1000
1002
Create a Plurality of Chunks on a Server
1004
Store a Global Mutation Log on the Server
1006
Receive a First Set of Mutations from a Plurality of Client Computers
1008
Take a Snapshot of the First Chunk
1010
Receive a Second Set of Mutations from the Plurality of Client Computers
1012
Apply Second Set of Mutations to the Snapshot
1014
Send the Modified Snapshot to the Client Computers

FIG. 10

DYNAMICALLY SIZING CHUNKS IN A PARTIALLY LOADED SPREADSHEET MODEL

BACKGROUND

Cloud storage systems provide users with the ability to store electronic documents and other files on a remote network rather than on a local computer. This allows users the ability to access the remotely stored files from any device that is capable of connecting with the remote network, for example using a web browser over an Internet connection. Users typically log into an account on the cloud storage system using a username and password. The cloud storage system provides a user interface for users to view, edit, and manage files stored on the system. Cloud storage systems also provide users the ability to share files with other users and to allow collaboration between users on the same file.

One type of file that may be stored in a cloud storage system is a spreadsheet. Spreadsheets are usually arranged as a set of rows and columns that define cells, where each cell may contain data, formulae, or other information. Spreadsheets range in size and larger spreadsheets may contain many rows or columns of information. Typically, when a file from a cloud storage system is loaded onto a client computer the data contents of the entire file are sent from the server to the client computer. For large spreadsheets, the amount of data may range in the megabytes or above. Downloading the information to the client computer may take a long time and may also slow down the rendering process on the client computer. In addition, if a user only wants to edit a certain portion of the spreadsheet, loading the entire spreadsheet onto the client computer wastes time and resources.

SUMMARY

The systems and methods described herein provide a data structure of a spreadsheet in a cloud storage system that may be quickly loaded onto a client computer regardless of the size of the spreadsheet. Only a portion of the spreadsheet may be loaded at a time, with other portions of the spreadsheet loaded as needed by the user. A cloud storage system includes one or more servers for storing files for a user, including spreadsheets. Each spreadsheet is represented by a plurality of chunks, where each chunk encompasses a range of cells in the spreadsheet. The cloud storage system maintains a set of chunks for the spreadsheet. Each user with write access to the spreadsheet may load chunks from the cloud storage system, where they are locally stored. Each client computer can then dynamically change its locally-stored set of chunks independent from the cloud storage system and other users. Any individual chunk in one set of chunks may or may not share the same attributes as any individual chunk in another set of chunks. A mutation log associated with the spreadsheet is stored on the cloud storage system. The mutation log records all mutations, or edits, made to the spreadsheet by a number of users with write access to the spreadsheet. The cloud storage system receives mutations from users, records them in the mutation log, and then broadcasts the mutations to other collaborators. When a user on a client computer requests the display of a range of cells of a spreadsheet stored on the cloud storage system, the cloud storage system applies the mutations stored in the mutation log to one or more of its chunks that span the range of cells of the spreadsheet requested. The cloud storage system sends the updated chunks to the client computer for display. The chunk boundaries for each user may be dynamically adjusted depending on the mutations received from each collaborator. The size of the chunks may be based on the memory and connection capabilities of the client computer associated with the chunks.

One aspect described herein discloses a method for managing a dynamically-sized chunked spreadsheet model on a server. The method includes creating, on the server, a plurality of chunks representing a spreadsheet, where a first chunk in the plurality of chunks includes a first range of cells in the spreadsheet. The method further includes storing on the server a mutation log for the spreadsheet, and receiving a first plurality of mutations from a plurality of client computers, where the first plurality of mutations are stored in the mutation log. The method further includes applying the first plurality of mutations to the first chunk in response to a first client computer in the plurality of client computers requesting the first range of cells, and sending the first chunk to the first client computer.

Another aspect described herein discloses a system for managing a dynamically-sized chunked spreadsheet model, the system including a server. The server is configured to communicate with a plurality of client computers using a communication connection, create a plurality of chunks representing a spreadsheet, where a first chunk in the plurality of chunks includes a first range of cells in the spreadsheet, and store a mutation log for the spreadsheet. The server is further configured to receive a first plurality of mutations from the plurality of client computers, where the first plurality of mutations are stored in the mutation log, apply the first plurality of mutations to the first chunk in response to a first client computer in the plurality of client computers requesting the first range of cells, and send the first chunk to the first client computer over the communication connection.

BRIEF DESCRIPTION OF THE DRAWINGS

The methods and systems may be better understood from the following illustrative description with reference to the following drawings in which:

FIG. **1** shows a client-server system for managing a dynamically-sized chunked spreadsheet model in accordance with an implementation as described herein;

FIG. **2** shows the components of a server configured for managing a dynamically-sized chunked spreadsheet model in accordance with an implementation as described herein;

FIG. **3** shows a spreadsheet with dynamically-sized chunks in accordance with an implementation as described herein;

FIG. **4** shows a mutation log for a spreadsheet with dynamically-sized chunks in accordance with an implementation as described herein;

FIG. **5** shows another spreadsheet with dynamically-sized chunks in accordance with an implementation as described herein;

FIG. **6** shows a dependency graph for a spreadsheet with dynamically-sized chunks in accordance with an implementation as described herein;

FIG. **7** shows another spreadsheet with dynamically-sized chunks in accordance with an implementation as described herein;

FIG. **8** shows another dependency graph for a spreadsheet with dynamically-sized chunks in accordance with an implementation as described herein;

FIG. **9** shows a method for managing a dynamically-sized chunked spreadsheet model in accordance with an implementation as described herein; and

FIG. **10** shows another method for managing a dynamically-sized chunked spreadsheet model in accordance with an implementation as described herein.

DETAILED DESCRIPTION

To provide an overall understanding of the systems and methods described herein, certain illustrative embodiments will now be described, including systems and methods for managing a dynamically-sized chunked spreadsheet model on a cloud storage system. However, it will be understood that the systems and methods described herein may be adapted and modified as is appropriate for the application being addressed and that the systems and methods described herein may be employed in other suitable applications, and that such other additions and modifications will not depart from the scope thereof. In particular, a server or system as used in this description may be a single computing device or multiple computing devices working collectively and in which the storage of data and the execution of functions are spread out among the various computing devices.

Aspects of the systems and methods described herein provide a cloud storage system capable of creating, storing, and managing an electronic document with dynamically-sized chunks. An exemplary electronic document that may be represented by dynamically-sized chunks is a spreadsheet, but presentation documents, word processing documents, or other electronic documents may also represented by dynamically-sized chunks. A spreadsheet may be represented by one or more chunks, where each chunk encompasses a range of cells in the spreadsheet. One or more servers hosting a cloud storage system maintains a set of chunks for the spreadsheet. Each user with write access to the spreadsheet may load chunks from the cloud storage system, where they are locally stored. Each client computer can then dynamically change its locally-stored set of chunks independent from the cloud storage system and other users. All chunks are initially empty. A mutation log is associated with the spreadsheet and stored on the server. The mutation log records all mutations made by users to the spreadsheet to any chunk of the spreadsheet. When a user on a client computer requests a range of cells of the spreadsheet from the server, the server applies all the mutations stored in the mutation log to one or more of its chunks representing the range of cells of the spreadsheet requested and sends the copies of the chunks to the client computer. Each chunk is also associated with a dependency graph, which stores the dependencies each cell in the chunk has on other cells. To improve chunk loading performance, snapshots of chunks may be stored and associated with the chunks, where the snapshot captures a chunk at a certain time. This allows the server to only apply mutations occurring after the snapshot rather than starting from an empty chunk. For example, a chunk may be associated with a time-ordered series of snapshots and the cloud storage system utilizes the most recent snapshot to generate an up-to-date version of the chunk. Older snapshots may be used as records of previous versions of the chunk.

A cloud storage system stores files for users and allows users to view, edit, share, and download those files using client computers connected to the cloud storage system over a remote network. One type of file that a cloud storage system may store is a spreadsheet. FIG. **1** illustrates a client-server system, where the server supports a cloud storage system for storing spreadsheets and other files. System **100** includes one or more servers **102** which collectively provide a cloud storage system for storing files such as spreadsheet file **104**. System **100** also includes a number of client computers **106***a* through **106***d* which connect to servers **102** through a remote network, such as the Internet. Each one of client computers **106***a* through **106***d* may be a desktop computer, laptop computer, mobile device, tablet, or any other computing device capable of connecting with servers **102**. The remote network connection may be a wired or wireless Internet connection, local area network (LAN), wide area network (WAN), Wi-Fi network, Ethernet, or any other type of known connection.

A cloud storage system may be configured to create and store a spreadsheet model using dynamically-sized chunks. First, a general cloud storage system is described in more detail. Server **200** in FIG. **2** shows an example of a server for use in a cloud storage system. A cloud storage system may include a number of servers that collectively provide the cloud storage service. Server **200** includes a central processing unit (CPU) **202**, read only memory (ROM) **204**, random access memory (RAM) **206**, input/output interface **208**, data store **210**, and bus **212**. Server **200** may have additional components that are not illustrated in FIG. **2**. Bus **212** allows the various components of server **200** to communicate with each other. Input/output interface **208** allows the server **200** to communicate with other devices, such as client computers or other servers in the cloud storage system. Data store **210** may store, among other things, files belonging to users of the cloud storage system. Data store **210** also stores dynamically-sized chunks for each user accessing a spreadsheet stored on the server, a dependency graph for each chunk, and a mutation log for each spreadsheet. Users connect with server **200** through input/output interface **208** to access files stored in data store **210**.

Data store **210** for providing cloud storage services may be implemented using non-transitory computer-readable media. In addition, other programs executing on server **200** may be stored on non-transitory computer-readable media. Examples of suitable non-transitory computer-readable media include all forms of non-volatile memory, media and memory devices, including, by way of example only, semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and readable, once-writable, or rewriteable CD-ROM and DVD-ROM disks.

A spreadsheet stored on a cloud storage system may be represented by one or more chunks. FIG. **3** shows an example spreadsheet **300** with dynamically-sized chunks. Spreadsheet **300** as illustrated has rows **1** through **14** and columns A through E, although a spreadsheet may include any number of rows and columns. The cloud storage system may represent the entire spreadsheet **300** using one or more chunks, where each chunk represents a range of cells in the spreadsheet. In FIG. **3**, chunk **302** represents rows **1** through **7** and chunk **304** represents rows **8** through **14**. Chunks may represent any range of rows, columns, or a combination of rows and column ranges. For example, a chunk may represent the first 1,000 rows of a spreadsheet, the second 1,000 rows of a spreadsheet, the first 1,000 columns of the spreadsheet, or a range of cells covered by rows **1** through **1,000** and columns **100** through **200**. For a small spreadsheet with 100 rows and 5 columns, the server may only create one chunk. For a large spreadsheet with 10,000 rows and 20 columns, the server may create 10 chunks, each spanning 1,000 rows. A spreadsheet file may include a number of individual sheets, each having its own tab, arranged in a "workbook" structure. Chunks may be created for each sheet within the spreadsheet file.

The server maintains a master set of chunks for a spreadsheet. Each user with write access to the spreadsheet may load chunks from the cloud storage system, where they are locally stored. Each client computer can then dynamically change its locally-stored set of chunks independent from the cloud storage system and other users. The server may initially set the chunks for each user to be identical, but the size and range of the chunks may be further customized by the client computer and may be based on the capabilities of each client computer that accesses the spreadsheet. For example, if the client computer is a desktop computer with a large cache, the chunk sizes may be large. If the client computer is a tablet or mobile device with smaller memory capabilities, the chunk sizes may be small. The chunk sizes may also be based on the bandwidth of the connection between the client computer and the server. The size and range of the chunks are not static, but may be dynamically changed by the client computer as edits are made to the spreadsheet. For example, if a user adds many rows to a portion of a spreadsheet covered by one chunk, the client computer may split the chunk into two chunks. If a user deletes many rows from a portion of a spreadsheet covered by one chunk, the client computer may merge the reduced chunk with another chunk. If a user adds one or deletes one row in a chunk, the client computer may adjust the boundaries of adjacent chunks. There may be a tolerance range so that repeated insertion and deletion of cells does not repeatedly invoke the merge and split functions, or the boundary adjustment of chunks. The effects of these edits, or mutations, on a chunked spreadsheet model will be discussed in further detail below. Each chunk has an associated ID to uniquely identify it. One of the chunks in the spreadsheet is designated to store metadata information about the entire spreadsheet, such as total number of rows and columns, name of the spreadsheet, chunk IDs, and any other commonly used metadata fields. This chunk may be the first chunk that is normally loaded when a user requests the spreadsheet (e.g. the chunk encompassing row **1** and column **1**).

In addition to representing a spreadsheet by one or more dynamically-sized chunks, a mutation log is associated with the spreadsheet. FIG. **4** shows an example of a mutation log **400**. The mutation log may apply to all chunks of a spreadsheet, so only one log is stored per spreadsheet. Alternatively, each chunk of the spreadsheet may have an associated mutation log. Mutation log **400** stores mutations, or edits, that all users with write access to the spreadsheet send to the cloud storage system, in the order in which they are received. The cloud storage system stores the mutations and also propagates the mutations to each collaborator that is also working on the same spreadsheet. These edits may be to set the value of cells, delete cell values, enter formulae into cells, cut, copy or paste values, add or delete rows and columns, sorting row or column values, filtering row or column values, linking to external data, performing a calculation, or any other operation permissible in an electronic spreadsheet. For example, mutation log **400** stores a number of set value commands, such as "Set A**2**=2" for mutation A, "Set A**3**=4" for mutation B, and "Set B**3**=A**2**+A**3**" for mutation C. Mutation log **400** may also store row addition and deletion mutations, such as "Delete Row **6**" for mutation I and "Add Row **11**" for mutation J. Other mutations not shown in FIG. **4** may also be stored in mutation log **400**. In case of conflicting mutations or mutations that occur at the same time, the server may engage various conflict resolution mechanisms to determine the proper order of mutations. The mutations correlate directly to cells, rows or columns, without regard to chunks. This allows the size and range of chunks to change without affecting mutation log **400**. The cloud storage system may assign a revision number to each mutation received. The syntax of the mutations is not limited to that shown in FIG. **4** but may encompass any known spreadsheet syntax.

FIG. **4** also shows two snapshots, one taken after mutation E and one taken after mutation J. Snapshots are copies of a chunk generated at a certain time with all the mutations occurring before that time incorporated into the chunk. For example, snapshot S**1** of a chunk incorporates mutations A-E while snapshot S**2** of a chunk incorporates mutations A-J. Snapshots are created by the cloud storage system to lessen the time it takes to load a chunk to a user. For example, when a user requests a chunk from a cloud storage system after mutation G has been entered, the cloud storage system takes an empty initial copy of the chunk and applies mutations A-G stored in mutation log **400** to the empty chunk to obtain the current state of the chunk, and then sends the chunk to the client computer. If the cloud storage system has created and stored snapshot S**1**, then it only needs to apply mutations F and G to snapshot S**1** of the chunk before sending the copy to the client computer.

When a spreadsheet is first generated in a cloud storage system, one or more chunks are created that represent the spreadsheet. Initially, all the cells in every chunk have no value (i.e. the spreadsheet is empty), such as shown in FIG. **3**. As the cloud storage system receives mutations for the spreadsheet from any number of users, the mutations are stored in a mutation log associated with the spreadsheet, such as shown in FIG. **4**. The cloud storage system also sends each mutation to the other collaborators who are working on the same spreadsheet, either individually or in batches. When a client computer requests a range of cells of the spreadsheet encompassed by a chunk, the cloud storage system applies all the mutations received up to that point and applies it to an empty version of the chunk (or a snapshot if one has been created). After all the mutations have been applied, a copy of the chunk is sent to the client computer. For example, mutation log **400** depicted in FIG. **4** is associated with empty spreadsheet **300** in FIG. **3**. One or more users send mutations A-E shown in FIG. **4** to the cloud storage system. The cloud storage system stores these mutations in mutation log **400**. Then a user on a client computer requests a copy of chunk **302** or chunk **304** of spreadsheet **300**. Alternatively, the cloud storage system may save a snapshot of both chunks after mutation E has occurred, such as snapshot S**1** illustrated in FIG. **4**. In either situation, spreadsheet **500** shown in FIG. **5** depicts the current state of both chunks after mutation E. The client computer stores the copy of the chunk received from the cloud storage system in local memory. The server sends the client computer mutations made by other collaborators on the spreadsheet, which are applied to the chunk at the client computer. If the client computer requires additional portions of the spreadsheet to be loaded, the client computer makes additional chunk requests to the cloud storage system.

Spreadsheet **500** includes chunk **502** and chunk **504**, which correspond to chunks **302** and **304** respectively in FIG. **3**, but shown after mutations A-E from mutation log **400** have been applied to the chunks. Mutation A, "Set A**2**=2", is applied to both chunk **502** and chunk **504**. Cell A**2** is found in chunk **502** and so it is set to the value "2", as illustrated. Chunk **504** does not include cell A**2**, so the application of mutation A to chunk **504** results in a null effect. Mutation B, "Set A**3**=4", is also applied to both chunks but has no effect on chunk **504** because cell A**3** is located in chunk **502**. Likewise with mutation C, which sets cell B**3**=A**2**+A**3**. Mutations D and E, however, produce a change in chunk **504** but no change in chunk **502**. After mutations A-E are applied to chunks **502** and **504**, cell A**2** has the value "2", cell A**3** has the value "4", cell B**3** has the value "6" (A**2**+A**3**), cell C**10** has the value "8" (A**2**×A**3**), and cell E**9** has the value "14" (B**3**+C**10**).

Each chunk is associated with a dependency graph which records any dependent relationships of cells within the chunk with other cells, either within the same chunk or in a different chunk. FIG. **6** shows two such dependency graphs, graph **602** associated with chunk **502** and graph **604** associated with chunk **504**. When the cloud storage system receives a mutation from a user, the cloud storage system applies the mutations to the dependency graphs for each chunk to ensure that relationships between cells are properly preserved. Thus mutations A-E in mutation log **400** are applied to chunks **502** and **504** as well as to graphs **602** and **604**. For example, mutation C specifies that the value of cell B**3** in chunk **502** depends on the values of cells A**2** and A**3** and so it is recorded in graph **602** as "A**2**:A**3**→B**3**". In chunk **504**, the values of cells C**10** and E**9** depend on the values of other cells in both chunk **502** and chunk **504**, so the dependency relationship for both cells is recorded in both graphs **602** and **604**. The structure and syntax of dependency graphs **600** is not limited to what is shown in FIG. **6** but may encompass any known structure and syntax for expressing relationships between spreadsheet cells. For example, the dependency graphs may be stored as an R-tree. When a user requests a chunk to be loaded on the user's client computer, the cloud storage system applies all the mutations to chunk and to its corresponding dependency graph and sends the chunk and the dependency graph to the client computer. The client computer queries the dependency graph to determine if any cells are dependent on cells in other chunks. The client computer may already have copies of the other chunks that are necessary to determine the cell values stored in local memory, but if the client computer does not have one or more necessary chunks, the client computer requests those chunks from the cloud storage system. The cloud storage system applies the mutations in the mutation log to those chunks and sends them to the client computer. Once the client computer has all the chunks necessary to determine the value of the cells in the first chunk, the client computer calculates the actual cell values for the chunk.

At a later time after mutations A-E were received, the cloud storage system receives mutations F-J for the spreadsheet and records the mutations in mutation log **400**. Spreadsheet **700** in FIG. **7** shows the state of chunks **702** and **704** (which correspond to chunks **302** and **304** respectively) after mutations A-J have been applied. For example, spreadsheet **700** may represent a snapshot of chunks **702** and **704** taken after mutation J has been received (snapshot S**2** in FIG. **4**), or a client computer may request a version of spreadsheet **700** after mutation J has been received and the cloud storage system returns chunks **702** and **704**. The cloud storage system may start with empty chunks **302** and **304** and apply mutations A-J to derive chunks **702** and **704**. Alternatively, if a snapshot of the chunks exists, the cloud storage system may start with the snapshots and apply only the mutations that are received after the snapshots. For example, chunks **502** and **504** may represent snapshots of the chunks after mutation E. When a client computer requests either chunk **702** or **704** after mutation J has been received, the cloud storage system applies mutations F-J to snapshot chunks **502** or **504** and returns chunk **702** or **704**, respectively.

Mutations F, G, and H in mutation log **400** are set value mutations and are applied to both chunk **702** and chunk **704**, producing a null effect in any chunks which are not affected by the mutations. Thus the value of cell D**1** is set to "3", the value of D**12** is set to "12", and the value of A**3** is set to "5". Mutation I deletes row **6** of spreadsheet **700**. When a row is deleted, the boundaries of chunks may change. For example, because row **6** was within chunk **702** before it was deleted, chunk **702** encompasses new rows **1-6** after the deletion of row **6** rather than rows **1-7** as originally defined. All rows below row **6** are shifted up one row. Thus chunk **704** now encompasses rows **7** through **13** and all the cell values in chunk **704** are shifted up one row. Mutation J inserts a new row as row **11**, which affects chunk **704** but not chunk **702**. Chunk **704** now encompasses rows **7** through **14** and the values of any cells at or below old row **11** are shifted down one row. After mutation J has been applied, the value of cell C**9** in chunk **704** is now set as A**2**×A**3**. C**10** was originally set to this value, but the deletion of row **6** shifted the value up one row to C**9**. Likewise, the original value of E**9**(B**3**+C**10**) has been shifted to E**8**. The value of D**12** was originally set to "12", was shifted up one row by the deletion of row **6**, and then shifted down one row by the addition of row **1**. Thus cell D**12** still contains the value "12".

Dependency graphs **802** and **804** in FIG. **8** show the dependency relationships for cells in chunks **702** and **704** respectively. Mutations F-J, in addition to being applied to the chunks, are also applied to graphs **802** and **804**. Both graphs have been affected by the row deletions and additions. For example, cell C**9** rather than cell C**10** depends on cells A**2** and A**3** because of the deletion of row **6**. Likewise, cell E**8** rather than cell E**9** depends on cells B**3** and C**9** because of the deletion of row **6**. Once dependency graphs **800** are updated with the mutations, the cloud storage system may send the dependency graphs along with a copy of the chunks when requested by a user. In this manner, FIGS. **3** through **8** show the operation of dynamically-sized chunks for a spreadsheet model implemented in a cloud storage system.

Methods for creating, storing, and delivering a dynamically-sized chunked spreadsheet model on a cloud storage system are now described. One method for managing a dynamically-sized chunked spreadsheet model on a server is illustrated in FIG. **9**. Method **900** includes creating, on the server, a plurality of chunks representing a spreadsheet, where a first chunk in the plurality of chunks includes a first range of cells in the spreadsheet. The method further includes storing on the server a mutation log for the spreadsheet, and receiving a first plurality of mutations from a plurality of client computers, where the first plurality of mutations are stored in the mutation log. The method further includes applying the first plurality of mutations to the first chunk in response to a first client computer in the plurality of client computers requesting the first range of cells, and sending the first chunk to the first client computer.

Method **900** begins when a server hosting a cloud storage system creates a spreadsheet, the spreadsheet including one or more chunks, illustrated at **902**. One or more servers such as server **200** in FIG. **2** may host the cloud storage system. This may be in response to a user saving a spreadsheet on the cloud storage system. Each chunk represents a range of cells in the spreadsheet, such as chunks **302** and **304** in spreadsheet **300** shown in FIG. **3**. For example, a chunk may represent a number of rows in the spreadsheet, or a number of columns in a spreadsheet. The spreadsheet file may be a workbook that includes a number of separate sheets and chunks are created for each sheet in the workbook. The spreadsheet may initially have only one chunk if the spreadsheet is empty. The server designates one chunk to store metadata information about the entire spreadsheet, such as total number of rows and columns, name of the spreadsheet, chunk IDs, and any other commonly used metadata fields. The server maintains a set of chunks for the spreadsheet. Each user with write access to the spreadsheet may load chunks from the cloud storage system, where they are locally stored. Each client computer can then dynamically change its locally-stored set of chunks independent from the cloud storage system and other users. Thus changes to the size and boundaries of one user's chunks do not affect the size or boundaries other users' chunks. For example, different users may be on client computers with different memory and connection capabilities and the client computer may optimize the chunk size for each client computer. The chunks are stored on the server in lieu of the full spreadsheet.

After a plurality of chunks for a spreadsheet are created, the server stores a mutation log associated with the spreadsheet, illustrated at **904**. The mutation log records all mutations, or edits, made by users with write access to the spreadsheet. Mutation log **400** shown in FIG. **4** is an example of a mutation log stored on the server. The server receives a plurality of mutations from one or more users using client computers to work on the spreadsheet, illustrated at **906**. Mutations may include commands to set cell values, commands to insert or delete rows or columns, cut, copy, and past commands, filtering row or column values, linking to external data, performing a calculation, and any other standard spreadsheet operations. The server may dynamically modify the range of cells of a chunk based on one or more of the mutations. For example, the server may adjust chunk row boundaries if it receives insert or delete row commands. The mutation log records all mutations in the order in which they are received. In case of conflicting mutations or mutations that occur at the same time, the server may engage various conflict resolution mechanisms to determine the proper order of mutations. The server also sends each received mutation to other collaborators who are also working on the spreadsheet. The mutations stored in the mutation log do not have any chunk information associated with them—they are independent of the chunks. This allows the mutations to be stored on a single mutation log applicable to all chunks. The mutations are not automatically applied to the chunks when they are received, but rather are stored in the mutation log. Each chunk may also have an associated dependency graph, which records the relationships cells within the chunk have with other cells. The plurality of mutations are applied to the dependency graph of each chunk so that the dependency relationships are up-to-date. Examples of dependency graphs in include graphs **602** and **604** shown in FIG. **6** and graphs **802** and **804** shown in FIG. **8**.

After a plurality of mutations are received by the server and stored in the mutation log, the server receives a request from a user on a client computer to send the client computer a copy of a range of cells of the spreadsheet, illustrated at **908**. For example, this may occur when a client computer requests a range of cells of the spreadsheet encompassed by a first chunk of which the client computer does not currently have a copy. When the request is received by the server, the server applies all the mutations stored in the mutation log to the first chunk on the server in the order in which they are stored. The chunk may initially be empty, so the mutations represent all the edits made by all users to that chunk of the spreadsheet. When all the mutations have been applied, the chunk is up-to-date with all user edits. For example, spreadsheet **500** in FIG. **5** shows up-to-date chunks **502** and **504** after mutations **1-5** listed in mutation log **400** have been applied to the chunk. The server then sends the up-to-date chunk to the client computer, illustrated at **910**. If the client computer requests another range of cells of the spreadsheet encompassed by another chunk, the server applies the plurality of mutations to this additional chunk and sends it to the client computer. If the client computer requests a range of cells of the spreadsheet encompassed by multiple chunks, the server applies the plurality of mutations to all the necessary chunks and sends them to the client computer. Unless there are snapshots of the chunk available, the server applies all of the plurality of mutations to any chunk when that chunk is requested by the client computer. In this manner, the server provides a method for managing a dynamically-sized chunked spreadsheet model.

Another method for managing a dynamically-sized chunked spreadsheet model on a server may use snapshots of chunks to decrease the time it takes to generate a chunk for sending to a client computer, as illustrated in FIG. **10**. Method **1000** includes creating, on the server, a first plurality of chunks representing a spreadsheet, where a first chunk in the plurality of chunks includes a first range of cells in the spreadsheet, and storing on the server a mutation log for the spreadsheet. The method further includes receiving a first plurality of mutations from a plurality of client computers, where the first plurality of mutations are stored in the mutation log, and storing a snapshot of the first chunk, where the first plurality of mutations are applied to the first chunk to obtain the snapshot. The method further includes receiving a second plurality of mutations from the plurality of client computers, where the second plurality of mutations are stored in the mutation log. The method further includes applying the second plurality of mutations to the snapshot to obtain a modified snapshot in response to a first client computer in the plurality of client computers requesting the first range of cells, and sending the modified snapshot to the first client computer.

Method **1000** begins when a server hosting a cloud storage system creates a spreadsheet, the spreadsheet including one or more chunks, illustrated at **1002**. One or more servers such as server **200** in FIG. **2** may host the cloud storage system. This may be in response to a user saving a spreadsheet on the cloud storage system. Each chunk represents a range of cells in the spreadsheet, such as chunks **302** and **304** in spreadsheet **300** shown in FIG. **3**. For example, a chunk may represent a number of rows in the spreadsheet, or a number of columns in a spreadsheet. The spreadsheet file may be a workbook that includes a number of separate sheets and chunks are created for each sheet in the workbook. The spreadsheet may initially have only one chunk if the spreadsheet is empty. The server designates one chunk to store metadata information about the entire spreadsheet, such as total number of rows and columns, name of the spreadsheet, chunk IDs, and any other commonly used metadata fields. The server maintains a set of chunks for the spreadsheet. Each user with write access to the spreadsheet may load chunks from the cloud storage system, where they are locally stored. Each client computer can then dynamically change its locally-stored set of chunks independent from the cloud storage system and other users. Thus changes to the size and boundaries of one user's chunks do not affect the size or boundaries other users' chunks. For example, different users may be on client computers with different memory and connection capabilities and the client computer may optimize the chunk size for each client computer. The chunks are stored on the server in lieu of the full spreadsheet.

After a plurality of chunks for a spreadsheet are created, the server stores a mutation log associated with the spreadsheet, illustrated at **1004**. The mutation log records all mutations, or edits, made by users with write access to the spreadsheet. Mutation log **400** shown in FIG. **4** is an example of a mutation log stored on the server. The server receives a first plurality of mutations from one or more users using client computers to work on the spreadsheet, illustrated at **1006**. Mutations may include commands to set cell values, commands to insert or delete rows or columns, cut, copy and paste commands, filtering row or column values, linking to external data, performing a calculation, and any other standard spreadsheet operations. The server may dynamically modify the range of cells of a chunk based on one or more of the mutations. For example, the server may adjust chunk row boundaries if it receives insert or delete row commands. The mutation log records all mutations in the order in which they are received. In case of conflicting mutations or mutations that occur at the same time, the server may engage various conflict resolution mechanisms to determine the proper order of mutations. The server also sends each received mutation to other collaborators who are also working on the spreadsheet. The mutations stored in the mutation log do not have any chunk information associated with them—they are independent of the chunks. This allows the mutations to be stored on a single mutation log applicable to all chunks. The mutations are not automatically applied to the chunks when they are received, but rather are stored in the mutation log. Each chunk may also have an associated dependency graph, which records the relationships cells within the chunk have with other cells. The first plurality of mutations is applied to the dependency graph of each chunk so that the dependency relationships are up-to-date. Examples of dependency graphs in include graphs **602** and **604** shown in FIG. **6** and graphs **802** and **804** shown in FIG. **8**.

After the first plurality of mutations are received by the server and stored in the mutation log, the server stores a snapshot of a first chunk, illustrated at **1008**. A snapshot captures the state of the first chunk after the first plurality of mutations are applied to the first chunk. For example, chunks **502** and **504** in FIG. **5** may be snapshots of chunks **302** and **304** respectively taken after the server receives mutations A-E listed in mutation log **400**. The server takes a copy of the first chunk and applies the first plurality of mutations to obtain the snapshot. The snapshot is stored on the server and associated with the first chunk. The snapshot allows the server to decrease the amount of time necessary to generate an up-to-date version of the first chunk when a client computer requests a copy of the hunk. After the snapshot has been stored, the server receives an additional second plurality of mutations from the one or more client computers, illustrated at **1010**. The second plurality of mutations are also stored in the mutation log. For example, mutations F-J listed in mutation log **400** shown in FIG. **4** may be received after the server takes a snapshot incorporating mutations A-E. The second plurality of mutations are applied to the dependency graph of each chunk so that the dependency relationships are up-to-date.

After the second plurality of mutations are received by the server and stored in the mutation log, the server receives a request from a user on a client computer to send the client computer the first chunk, illustrated at **1012**. For example, this may occur when a client computer requests a range of cells of the spreadsheet encompassed by the first chunk. When the request is received by the server, the server applies the second plurality of mutations stored in the mutation log to the snapshot. Applying only the second plurality of mutations to the snapshot takes less time than applying both the first and second plurality of mutations to the initial first chunk. Both processes would lead to the same result. A modified snapshot is obtained after the second plurality of mutations have been applied to the snapshot. For example, mutations F-J listed in mutation log **400** may be applied to snapshot **502** in FIG. **5**, where snapshot **502** already incorporates mutations A-E. The result is modified snapshot **702** shown in FIG. **7**, which may also be obtained if mutations A-J were applied to empty chunk **302** in FIG. **3**. The server sends the modified snapshot to the client computer, illustrated at **1014**. The server may take additional snapshots of the first chunk as more mutations are received. If a client computer requests a copy of the first chunk, the server takes the most recent snapshot of the first chunk and only applies mutations received after that snapshot was stored. The server sends this modified snapshot to the client computer. Because each client computer maintains separate sets of chunks, each chunk within each set may have one or more snapshots associated with it. In this manner, the server provides a method for managing a dynamically-sized chunked spreadsheet model using snapshots to decrease the time to deliver chunks to a client computer.

It will be apparent that aspects of the systems and methods described herein may be implemented in many different forms of software, firmware, and hardware in the implementations illustrated in the figures. The actual software code or specialized control hardware used to implement aspects consistent with the principles of the systems and method described herein is not limiting. Thus, the operation and behavior of the aspects of the systems and methods were described without reference to the specific software code—it being understood that one of ordinary skill in the art would be able to design software and control hardware to implement the aspects based on the description herein.

Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous.

What is claimed is:

1. A method for managing a dynamically-sized chunked spreadsheet model on a server, the method comprising:

creating, on the server, a plurality of chunks representing a spreadsheet, wherein a first chunk in the plurality of chunks comprises a first range of cells in the spreadsheet;

storing on the server a mutation log for the spreadsheet;

receiving a first plurality of mutations from a plurality of client computers, wherein the first plurality of mutations are stored in the mutation log;

applying the first plurality of mutations to the first chunk in response to a first client computer in the plurality of client computers requesting the first range of cells;

modifying the range of cells that comprise the first chunk based on the first plurality of mutations, wherein:

when at least one of the plurality of mutations comprises deleting at least one row from a portion of the spreadsheet covered by the first chunk, determining whether the application of the at least one of the plurality of mutations reduces the size of the first chunk below a predetermined threshold, and merging the first chunk with a different chunk from the plurality of chunks, or,

when at least one of the plurality of mutations comprises adding at least one row to a portion of the spreadsheet covered by the first chunk, determining whether the application of the at least one of the plurality of mutations increases the size of the first chunk above the predetermined threshold, and splitting the first chunk into two chunks; and

sending the first chunk to the first client computer.

2. The method of claim **1**, wherein a second chunk in the plurality of chunks comprises a second range of cells in the spreadsheet, the method further comprising:

applying the first plurality of mutations to the second chunk in response to the first client computer requesting the second range of cells; and

sending the second chunk to the first client computer.

3. The method of claim **2**, wherein the first client computer requests the first and second range of cells at the same time.

4. The method of claim **1**, wherein the range of cells of the first chunk is a range of rows in the spreadsheet.

5. The method of claim **1**, wherein a first mutation in the first plurality of mutations is selected from the group consisting of a cut command, a copy command, a paste command, a set value command, an insert row command, a delete row command, an insert column command, a delete column command, a filter command, a sort command, an external link command, and a calculation command.

6. The method of claim **1**, wherein the first chunk is associated with a dependency graph.

7. The method of claim **6**, wherein receiving the first plurality of mutations includes applying the first plurality of mutations to the dependency graph.

8. The method of claim **6**, wherein the dependency graph is sent to the first client computer along with the first chunk.

9. The method of claim **1**, the method further comprising:

storing a snapshot of the first chunk, wherein the first plurality of mutations are applied to the first chunk to obtain the snapshot;

receiving a second plurality of mutations from the plurality of client computers, wherein the second plurality of mutations are stored in the mutation log;

applying the second plurality of mutations to the snapshot to obtain a modified snapshot in response to the first client computer requesting the first range of cells;

modifying the range of cells that comprise the first chunk based on the second plurality of mutations, wherein:

when at least one of the plurality of mutations comprises deleting at least one row from a portion of the spreadsheet covered by the first chunk, determining whether the application of the at least one of the plurality of mutations reduces the size of the first chunk below a predetermined threshold, and merging the first chunk with a different chunk from the plurality of chunks, or,

when at least one of the plurality of mutations comprises adding at least one row to a portion of the spreadsheet covered by the first chunk, determining whether the application of the at least one of the plurality of mutations increases the size of the first chunk above the predetermined threshold, and splitting the first chunk into two chunks; and

sending the modified snapshot to the first client computer.

10. The method of claim **1**, wherein each client computer in the plurality of client computers maintain separate sets of the plurality of chunks.

11. The method of claim **1**, wherein each mutation in the first plurality of mutations does not include any information about the plurality of chunks.

12. A system for managing a dynamically-sized chunked spreadsheet model, the system comprising:

a server, wherein the server is configured to:

communicate with a plurality of client computers using a communication connection;

create a plurality of chunks representing a spreadsheet, wherein a first chunk in the plurality of chunks comprises a first range of cells in the spreadsheet;

store a mutation log for the spreadsheet;

receive a first plurality of mutations from the plurality of client computers, wherein the first plurality of mutations are stored in the mutation log;

apply the first plurality of mutations to the first chunk in response to a first client computer in the plurality of client computers requesting the first range of cells;

modify the range of cells that comprise the first chunk based on the first plurality of mutations, wherein:

when at least one of the plurality of mutations comprises deleting at least one row from a portion of the spreadsheet covered by the first chunk, determine whether the application of the at least one of the plurality of mutations reduces the size of the first chunk below a predetermined threshold, and merge the first chunk with a different chunk from the plurality of chunks, or,

when at least one of the plurality of mutations comprises adding at least one row to a portion of the spreadsheet covered by the first chunk, determine whether the application of the at least one of the plurality of mutations increases the size of the first chunk above a predetermined threshold, and split the first chunk into two chunks; and

send the first chunk to the first client computer over the communication connection.

13. The system of claim **12**, wherein a second chunk in the plurality of chunks comprises a second range of cells in the spreadsheet, and wherein the server is further configured to:

apply the first plurality of mutations to the second chunk in response to the first client computer requesting the second range of cells; and

send the second chunk to the first client computer.

14. The system of claim **13**, wherein the first client computer requests the first and second range of cells at the same time.

15. The system of claim **12**, wherein the range of cells of the first chunk is a range of rows in the spreadsheet.

16. The system of claim **12**, wherein a first mutation in the first plurality of mutations is selected from the group consisting of a cut command, a copy command, a paste command, a set value command, an insert row command, a delete row command, an insert column command, a delete column command, a filter command, a sort command, an external link command, and a calculation command.

17. The system of claim **12**, wherein the first chunk is associated with a dependency graph.

18. The system of claim **17**, wherein the server is further configured to apply the first plurality of mutations to the dependency graph.

19. The system of claim **17**, wherein the dependency graph is sent to the first client computer along with the first chunk.

20. The system of claim 12, wherein the server is further configured to:

store a snapshot of the first chunk, wherein the first plurality of mutations are applied to the first chunk to obtain the snapshot;

receive a second plurality of mutations from the plurality of client computers, wherein the second plurality of mutations are stored in the mutation log;

apply the second plurality of mutations to the snapshot to obtain a modified snapshot in response to the first client computer requesting the first range of cells;

modify the range of cells that comprise the first chunk based on the second plurality of mutations, wherein:

when at least one of the plurality of mutations comprises deleting at least one row from a portion of the spreadsheet covered by the first chunk, determine whether the application of the at least one of the plurality of mutations reduces the size of the first chunk below a predetermined threshold, and merge, the first chunk with a different chunk from the plurality of chunks, or,

when at least one of the plurality of mutations comprises adding at least one row to a portion of the spreadsheet covered by the first chunk, determine whether the application of the at least one of the plurality of mutations increases the size of the first chunk above a predetermined threshold, and split the first chunk into two chunks; and

send the modified snapshot to the first client computer over the communication network.

21. The system of claim 12, wherein each client computer in the plurality of client computers maintain separate sets of the plurality of chunks.

22. The system of claim 12, wherein each mutation in the first plurality of mutations does not include any information about the plurality of chunks.

* * * * *